LASER-INDUCED PLASMA

A VERSATILE TOOL FOR CHEMICAL ANALYSIS

Laser-Induced Plasma, such as Laser Induced Breakdown Spectroscopy (LIBS) and Laser Induced Fluorescence (LIF), makes real-time and in-situ analysis possible.

LIBS Uses Laser to Induce Plasma

In principle, LIBS is similar to ICP (Inductively Coupled Plasma). The difference is that instead of using an electrode, LIBS uses laser to induce plasma. LIBS has been an active research topic since the 1960's, and is being moved to a variety of field applications since the introduction of dependable compact pulsed lasers, sensitive high speed detector arrays, and low loss optical fiber cables.

As shown in Figure 1, a basic LIBS system consists of a sufficiently power laser, a fiber optic cable, a spectrometer, and a photodiode. The laser commonly used is of neodymium yttrium garnet (Nd:YAG) type, which produces up to 420 millijoules of energy at 1.064 microns in a 5-7 nanosecond pulse with a repetition rate of 20 Hz.

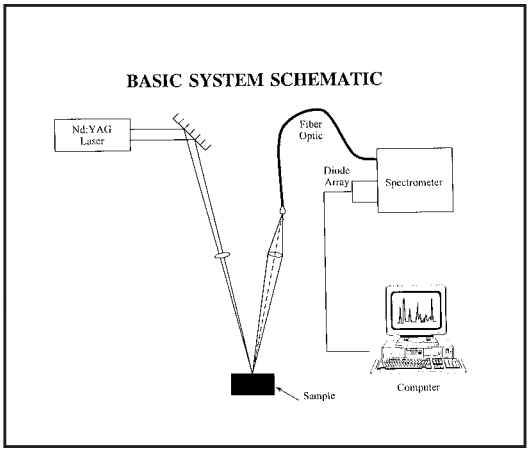

Figure 1. Schematic diagram of LIBS. *The plasma is formed by focusing optical pulses from a sufficiently power laser.*

LIBS Has Advantages Over ICP

As given in Table 1, LIBS are superior to ICP in many respects. Those unique features make LIBS a promising technique for filed-based and industrial applications:

- Real-time analysis for process control
- In-situ analysis in inaccessible locations and hostile environments
- Field sorting analysis such as for geological samples

LIF (Laser Induced Fluorescence) Enhances Sensitivity

One of the disadvantages of LIBS is the significant matrix effect, which lowers the sensitivity of LIBS. LIF,

Table 1. Comparison of LIBS and ICP. The Crater produced by laser shot is only about 1 mm in diameter and about 70-80 micron in depth.

LIBS	ICP
Field Portable Device	Laboratory Device
No Sample Preparation	Sample Dissolved and Nebulized
Small Sample Size (mili- to nano- gram)	Relative Large Sample Size
High Spatial Resolution	Relative low Spatial Resolution
Works on Solids, Liquids, and Gases	Works on Aqueous Aerosol

(over)

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however, can improve the detectability by one order. In LIF, a second pulsed-laser beam is used to selectively excite the metal atoms causing them to emit a pulse of fluorescent light at a characteristic wavelength.

INEEL (Idaho National Engineering and Environmental Laboratory) - A Leader in LIBS Technology

The Plasma and Applied Optics Department at INEEL has extensive experience in the development and application of optical instrumentation.

INEEL Is the Scene of Some of the Most Advanced Research Programs in The World

INEEL, being operated by Bechtel BWXT Idaho for the U. S. Department of Energy, is the home of the largest concentration of technical professionals in the northern Rocky Mountain region. Founded in 1949, INEEL has made strong technical contributions to regional and national programs in the areas of energy availability, waste management, defense systems, earth sciences, and engineered systems. The INEEL site covers nearly 570,000 acres and it currently has about 9,000 employees, among them more than 3,000 with engineering and science degrees.

INEEL Has the Leading Edge in Optical Instrumentation Development And Application

The INEEL Plasma and Optics Application Department is specialized in the following fields:

- High speed grating spectroscopy
- Pulse laser spectroscopy
- Radiometry
- Specialized imaging system

Here are two examples of field-based and mining related applications:

- **Real-Time Transuranic Dust Monitoring (RTDM)** - An in-situ device uses optically-based measurements to rapidly establish size and density of particles, and concentrations of heavy metal species in the dust generated in the remediation activities.
- **Preliminary Study of an On-Line Copper Cathode Analyzer** - A project to assess the feasibility of using LIBS for on-line analyzing contaminants in copper cathode. Six contaminants including Ni, Pb, Ag, Sn, Fe and Te were detected to low ppm levels (see Figure 2 and Table 2). Although the sensitivities are not very satisfactory, LIBS is certainly a promising technique in this field and several modifications will be probed for improvement.

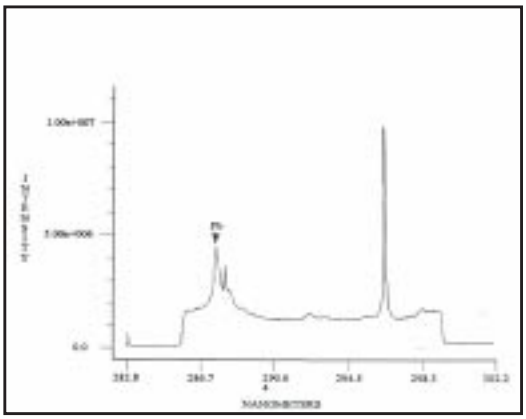

Figure 2. A Spectral Scan of Lead. *The sample contained 114 ppm Pb and the scan was performed with a 2400 l/mm grating.*

Contaminants	Detection Level (ppm)
Nickel	19.6
Lead	1.4
Tin	2.2
Silver	1.0
Iron	3.0
Tellurium	0.75

Table 2. Detection Limits. All the detection levels are in ppm except Nickel.

INEEL is Willing to Work Together with You for Implementing the State-of-Art LIBS Technique in Your System

INEEL will work closely with you to develop the LIBS/LIF method and instrument based on your needs. Different procedures will be tailed to fit into different situations of yours. The following example is a step by step procedure for developing a on-line LIBS to measure lanthanide in operation control:

1. Develop detailed system operating requirements
2. Prepare samples for testing
3. Perform scope tests to select the best analytical wavelengths
4. Conduct interference testing
5. Optimize operational parameters and produce a calibration curve for each sample stream
6. Define the best method and relative accuracy for total lanthanide determination of each and all streams
7. Establish method for reading samples from moving belt and moving slurries
8. Define instrument configuration, cost, installation, and service requirements
9. Prepare a summary report

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